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Engineering Study: Trolley Turntables Design Development Plan

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BSC ENGINEERING STUDY

100-30R-WHS0-00300-000

Revision 000

June 2005

TROLLEY TURNTABLES

DESIGN DEVELOPMENT PLAN

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ACRONYMS

DDP	design development plan
DTF	Dry Transfer Facility
FMEA	failure mode and effects analysis
FTA	fault tree analysis
ITS	important to safety
NSDB	<i>Nuclear Safety Design Bases for License Application</i>
SSCs	systems, structures, and components

1. PURPOSE

The purpose of this design development plan (DDP) is to identify major milestones for advancing the design of the trolley turntables to meet their credited safety functions, as identified in *Nuclear Safety Design Bases for License Application* (NSDB) (BSC 2005), where this objective cannot be achieved by the use of commercially available components or the application of industry consensus codes and standards. Furthermore, this DDP defines the planned approach and schedule logic ties for the design development activities, if and when required, and provides a basis for the subsequent development of performance specifications, test specifications, and test procedures. At this time no design development needs have been identified for the trolley turntables.

2. SCOPE

The scope and extent of this DDP is driven by the development requirements defined within the *Turntables—Gap Analysis Table* (COGEMA 2005). This DDP applies to areas of the trolley turntables design where performance confirmation cannot be readily obtained through the use of standard systems, structures, and components (SSCs) (e.g., cranes) or consensus codes and standards. Since no such areas have been identified in the gap analysis, this document outlines the approach that will be used should design development requirements be identified as the design advances.

The scope of this DDP is limited to identifying the planned approach and design development activities necessary to advance the design of the trolley turntables to demonstrate that they will meet the credited safety functions. Thereafter, this DDP will form the basis for defining design development and testing requirements within the trolley turntables performance specification. The performance specification will define the codes and standards and performance requirements for the design, fabrication, and testing of the equipment. Testing activities will be detailed in test specifications and test procedures. Test specifications will detail the requirements for each test, and testing procedures will prescribe how each test is to be performed.

This DDP is prepared by the Dry Transfer Facility (DTF) Team and is intended for the sole use of the Engineering department in work regarding the trolley turntables. Yucca Mountain Project personnel from the Cask/MSR/WP preparation system and remediation system should be consulted before use of this DDP for purposes other than those stated herein or by individuals other than those authorized by the Engineering department.

3. PROGRESSIVE APPROACH

A practical design philosophy has been adopted relying on proven concepts and technology used by other similar nuclear facilities. Design development requirements and activities identified within this plan are commensurate with the level of design completed for license application and the associated gap analysis study. Therefore, specific design details, and the selection of SSCs, may not be known, and all design development requirements may not have been identified within the gap analysis study.

For this reason, within this DDP, a progressive design development approach is presented that provides a framework whereby design development requirements and activities can be identified

and detailed as the design advances. However, as the design advances, it is anticipated to the extent practical that components or SSCs that perform ITS functions will be selected based on proven technology and codes and standards that provide assurance that they will perform, as required, without need for extensive design development.

This progressive design development approach includes, as appropriate, the design development activities identified in Section 9. Completion of each design development activity and advancement of the design will determine the need for further design development and completion of additional design development activities.

This progressive approach will maintain flexibility throughout the design process to allow alternative solutions to be explored without compromising project design development objectives.

4. DESIGN DEVELOPMENT OBJECTIVES

It can be seen from the *Turntables-Gap Analysis Table*, (COGEMA 2005) that all of the nuclear safety design requirements for the trolley turntables have been satisfied through the application of codes and standards and no design development requirements were identified. Therefore, the design activities described in sections 9 and 10 are not currently needed but included for completeness for possible use at a later date as the design advances. Full testing of standard SSCs as identified in the *Turntables-Gap Analysis Table*, (COGEMA 2005) will be included in the performance specification at a later date.

5. QUALITY ASSURANCE

This document was prepared in accordance with LP-ENG-014-BSC, *Engineering Studies*. The results of this document are only to be used as the basis for selecting design development activities; they are not to be used directly to generate quality products. Therefore, this engineering study is not subject to the requirements of *Quality Assurance Requirements and Description* (DOE 2004).

6. USE OF COMPUTER SOFTWARE

The computer software used in this study (Microsoft Word 2000) is classified as exempt from procedure LP-SI.11Q-BSC, *Software Management*. All software used to prepare this analysis is listed as software not subject to this procedure (LP-SI.11Q-BSC, Section 2.1).

7. FUNCTIONAL DESCRIPTION

Trolley turntables are a key component of the rail network used in the movement of cask trolleys throughout the DTF. The trolley turntables are used at three locations within the DTF to rotate or align cask trolleys to a new set of rails.

Two trolley turntables are part of the Cask/MSD/WP preparation system and the third is part of the remediation system. The trolley turntables are classified as ITS. The equipment numbers are 110-MJ-HMH0-TURN0001, 110-MJ-HMH0-TURN0002, and 130-MJ-HRD0-TURN0001. Within the DTF, trolley rails are classified as ITS, including the rails on the trolley turntables.

The trolley turntables interface with the following equipment:

- DTF rail network
- Cask trolleys
- Electrical power system.

Trolley turntables are designed using structural steel and standard materials and components used in the design and manufacture of heavy industry turntables. Trolley turntables consist of steel assemblies and parts and are designed to support cask trolleys handling loaded casks containing radioactive material. The elements of the design take proven design concepts and employ these concepts for this application.

Each turntable is expected to have two electric motors. One motor rotates the turntable by powering drive gears that mesh with ring gears at the turntable base. The second motor engages and disengages a locking mechanism that holds the turntable in position when aligned with the trolley rails. Mechanical stops are incorporated that prevent movement of the cask trolley if the trolley turntable is misaligned with the trolley rails.

8. NON-STANDARD SSCs

Non-standard SSCs are defined as; SSCs not based on commercially available equipment, established industry practices, or consensus codes and standards. The preferred practice is to use standard components and SSCs where the failure modes, failure effects, and reliability values are documented under similar operating conditions and environments.

The *Turntables-Gap Analysis Table*, (COGEMA 2005) identified SSCs that perform ITS functions, and it identified the codes and standards to be used to provide assurance that the ITS SSCs will perform as required. In all cases, ITS functions and requirements could be met using standard SSCs and using codes and standards developed for nuclear applications. The *Turntables-Gap Analysis Table*, (COGEMA 2005) did not identify any non-standard SSCs that require design development.

9. DESIGN DEVELOPMENT ACTIVITIES

If a design development requirement is identified, the following design development activities represent the progressive design development approach to advance the design of the trolley turntables. In turn, as the design advances, the need to complete each design development activity or selectively complete activities should be determined based on meeting each credited safety function. Design development activities are described in Section 10.

- Design Activities
 - Selection of SSCs
 - Engineering calculations
 - Computer modeling

- Failure mode and effects analysis
- Fault tree analysis (FTA)
- Testing Activities
 - Bench testing
 - Prototyping
 - Integrated testing.

As reflected in Appendix A, there are no specific design development requirements identified in the *Turntables—Gap Analysis Table* (COGEMA 2005). Although proven technologies and adaptations of similar designs will be used to the extent practical, design development requirements may be identified in the future.

10. DESIGN DEVELOPMENT ACTIVITY DESCRIPTIONS

Based on the existing design of the trolley turntables, no gaps have been identified between the design and codes and standards used to meet the safety requirements. Therefore, no specific design development activities are identified in the *Turntables—Gap Analysis Table* (COGEMA 2005). The following design development activity descriptions are included to accommodate future design development needs, should they be identified.

10.1 SELECTION OF SSCs

To the extent practicable, SSCs will be selected based on proven technologies that have been used in similar environmental and nuclear operating conditions. Selection of SSCs with proven nuclear pedigrees and well-documented histories may reduce the need for subsequent design development, and SSCs certified to IEEE Std 323™-2003, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations* may require little or no physical design development activities. In contrast, the selection of new technologies may require testing to confirm the adequacy of the equipment design under normal, abnormal, design basis event, and post-design basis event conditions, as well as the suitability of the materials and methods of construction.

10.2 ENGINEERING CALCULATIONS

As the design progresses and solutions are evaluated, especially for structural components, engineering calculations may be required to confirm that acceptable stress and strain levels are maintained and that maximum deflections are not exceeded. Validation of the SSCs may be demonstrated through calculations, and where necessary as a prerequisite to three-dimensional modeling and finite element modeling.

10.3 COMPUTER MODELING

Computerized, three-dimensional simulation modeling may be conducted for design verification during the advancement of the SSCs detail design to ensure that the SSCs will perform as required. Three-dimensional modeling may also be applied to the SSCs to verify performance

acceptance as alternative design options are considered. Finite element modeling may be used during design development to provide evidence that design stress levels are not exceeded.

10.4 FAILURE MODE AND EFFECTS ANALYSIS

A failure mode and effects analysis (FMEA) may be performed on the SSCs using ANSI/IEEE Std 352-1987, *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems*.

The FMEA is usually the first reliability activity performed to provide a better understanding of the failure potential of a design. The FMEA may be limited to a qualitative assessment, but may include numerical failure probability estimates. Important applications of the FMEA include:

- Specifying future tests required to establish whether design margins are adequate relative to specific failure mechanisms identified in the FMEA
- Identifying “safe” and “unsafe” failures for use in the quantitative evaluation of safety-related reliability
- Identifying critical failures that may dictate the frequency of operational tests and maintenance intervals if the failure modes cannot be eliminated from the design
- Establishing the quality-level for parts (especially electrical parts) needed to meet reliability goals
- Identifying unacceptable failure mechanisms (failures that may produce unacceptable safety or operational conditions) and the need for design modifications to eliminate them
- Identifying the need for failure detection.

FMEA may be used to identify, by component, all known failure modes, failure mechanisms, effects on the system, the method of failure detection, and provisions in the design to compensate for the failures. The analysis may provide established reliability statistics based on failure rates for components used in similar applications and environmental conditions. Reliability data, where available, will be obtained from nuclear facilities with similar quality control requirements. This activity is a prerequisite to performing a detailed fault tree analysis, and it provides the first level of design validation during the conceptual design phase. The FMEA may be periodically updated to reflect changes in design as the design matures.

10.5 FAULT TREE ANALYSIS

The following Fault tree Analysis (FTA) standard may be used to perform a FTA on the SSCs using guidance in accordance with ANSI/IEEE Std 352-1987, *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems*.

Where quantitative reliability requirements have been established in the *Nuclear Safety Design Bases for License Application* (BSC 2005) a fault tree analysis may be used to assess reliability.

The fault tree analysis, performed in conjunction with the results of the FMEA, may provide adequate design validation to proceed with prototype testing. Important benefits of FTA include:

- Identifying possible system reliability and safety problems during the design phase
- Assessing system reliability and safety during operation
- Improving the understanding of the component interactions within a system
- Identifying components that may need testing or more rigorous quality assurance scrutiny
- Identifying root causes of equipment failures.

10.6 BENCH TESTING OF COMPONENTS

Components that do not have a proven history of operating in environments similar to those expected at Yucca Mountain may be subject to bench testing at a testing facility capable of handling and duplicating the SSCs bounding environmental conditions.

Bench testing may be used to validate the following, in consideration of the above mentioned conditions:

- Suitability of materials used in the construction of components and assemblies
- Methods and techniques used in the construction of assemblies
- Lubricants used in or on components and assemblies
- The surface-finish of the components and assemblies (natural or painted)
- Evidence that components and assemblies will function properly over their expected operating life.

10.7 PROTOTYPE TESTING

The basic approach for prototype testing is to test the SSCs in an environment that simulates the actual operating environment as closely as possible. Prototype testing may be performed at full-scale because some components are unavailable at reduced scale. Full-scale prototype testing is recommended because:

- Scalability of the results from a scale model is questionable for enclosure thermal life predictions.

- A scale model approach implies a throwaway model at the conclusion of testing. It is anticipated that the initial SSCs can be used as a production or training unit with minor modifications and refurbishment.
- It is questionable whether scale components are available in all cases.
- The full-scale prototype approach is likely the low-cost plan.

Full-scale testing may also provide the most representative information to the final production equipment. Selection of individual components may consider their influence on test results. Where practicable, components that are identified as ITS may be identical to those to be used in the final production unit.

Prototype testing may be performed in the following three phases:

- Phase I: Accelerated testing
- Phase II: Extended testing
- Phase III: Sustained testing.

Prototype testing may establish data for the predictable life of components. Data may be established for the mechanical drive trains, control components, and field-mounted devices that are susceptible to premature failure in harsh environments. These data are important for validating equipment performance and recovery operations and for demonstrating equipment maintenance. Testing may simulate accelerated component life cycles and operating environments.

10.7.1 Accelerated Testing

Accelerated testing may simulate the full life-cycle operations of SSCs for all moving parts (e.g., motors, gearboxes, shafts, and brakes) in a compressed time period. This activity may also include full life-cycle control sequence testing of the control system, including the programmable logic controller, all control instrumentation, switches, sensors, and cabling. The control and instrumentation cabinets may be full life cycle tested relative to the SSCs environmental conditions.

Appendix B is used to tabulate ITS SSCs and prototype accelerated tests. No prototype testing is anticipated for the trolley turntables.

10.7.2 Extended Testing

Extended testing may simulate extended life-cycle operations for all moving parts (e.g., motors, gearboxes, shafts, and brakes) of the SSCs. This activity may also include full life-cycle control sequence testing of the control system, including the programmable logic controller, all control instrumentation, switches, sensors, and cabling. The control and instrumentation cabinets may also be full life cycle tested to the SSCs environmental conditions.

Appendix B is used to tabulate ITS SSCs and prototype extended tests. No prototype testing is anticipated for the trolley turntables.

10.7.3 Sustained Testing

Sustained testing may simulate the SSCs performance under off-normal environmental and operational conditions. Off-normal conditions include, for example, high and low temperatures, over travel, collisions, off-set loads, loss of power, seizure of moving parts, derailments, and track misalignment. Details that may be considered during sustained testing, and the components to test include, all load path and linear travel components, testing at a minimum, moving parts seizure.

Appendix B is used to tabulate ITS SSCs and prototype sustained tests. No prototype testing is anticipated for the trolley turntables.

10.8 OFFSITE INTEGRATED TESTING

Off-site integrated testing may be performed to demonstrate relevant interfaces. Furthermore an off-site test facility may also serve as an operator training facility. Integrated testing may be fully representative, to the extent practicable, of real operations with the exception of a radioactive environment.

Due to the nature of the SSCs, integrated testing is recommended to support the following goals:

- Demonstrate functionality of the complete system under simulated operational conditions
- Demonstrate the practicality of recovery and retrieval plans
- Verify the system performance prior to delivery to site
- Provide preparation for operational readiness review
- Permit early hands-on involvement of regulatory agencies
- Permit early operator training capabilities
- Provide early feedback for necessary modifications or design enhancements.

10.9 OPERATIONAL READINESS REVIEW

Although operational readiness review is beyond the scope of this DDP, it is mentioned here for completeness. The operational readiness review should follow offsite integrated testing and highlights the final milestone in demonstrating the performance of production ITS SSCs.

11. INFORMATION COLLECTION AND INSPECTION REQUIREMENTS

Although, individual components may be selected based on previous use in similar nuclear applications, it is unlikely that they have been used within the same configuration or for exactly the same application, and therefore component failure or excessive wear may be influenced by unknown interactions. Therefore, to evaluate component failures, it is essential that information be collected during each stage of the component life (i.e., manufacture, construction and operation). This information may then be used to ensure that a root cause analysis can be performed on the components that do not meet design and performance objectives.

Appendix C is used to identify typical data collection requirements. No data collection activities are anticipated for the trolley turntables.

11.1 BASELINE DATA

To assess wear and failure modes of ITS components during and after testing, it may be essential that detailed baseline data be obtained. The data, at a minimum, may include a physical inspection of each component before and after testing to identify defects and anomalies. Typical data should include weights, key dimensions, and surface finishes.

11.2 ACCELERATED TEST DATA

Throughout life-cycle prototype testing, sufficient instrumentation may be provided to monitor the performance of ITS components. Instrumentation may provide real-time monitoring and feedback on important measurements and operating parameters. Measurements, at a minimum, may include.

- The effects of temperature on components and fabrications caused by environmental temperatures coupled with the heat developed by components during operation (e.g., motors, gearboxes, bearings, speed control equipment, sensors, switches, cables, and relays).
- The ventilation system for the control cabinets may be monitored to ensure acceptable temperatures for the electronic components (e.g., switches, relays, and cables).
- The effects of the design loads on all load bearing components and fabrications may be monitored for stress and strain levels, physical deflections, and reductions in surface finish on load-path components (e.g., shafts, bearings) caused by wear.
- Motor power requirements may be recorded during equipment operations.
- Load path components (e.g., motors, gearboxes, and bearings) may be monitored for vibration and sound during operating cycles.
- The speed control systems for equipment travel and lifting may be monitored under all conditions.
- Instrumentation where practicable may include visual and audible feedback.

During accelerated testing, components may be inspected and maintained (e.g., adjustments and lubrication) as part of a scheduled maintenance regime based on vendor data. Where practicable, supplement vendor data with predictive maintenance and condition-monitoring techniques.

11.3 EXTENDED TEST DATA

Data requirements for extended testing are similar to those for accelerated testing, with the exception that a detailed inspection of each ITS component needs to be performed prior to testing to determine component wear, and life expectancy.

11.4 SUSTAINED TEST DATA

Data requirements for sustained testing are similar to those for accelerated testing, with the exception that a detailed inspection of each ITS component needs to be performed after each sustained test evolution to monitor for the evidence of progressive fatigue, cumulative fatigue, and component failure.

11.5 OFFSITE INTEGRATED TEST DATA

After prototype testing of individual components is complete, it may be necessary to demonstrate the overall functionality of the complete system. This phase of testing is referred to as integrated testing. To the extent practicable, integrated testing may be used to demonstrate the performance of the complete system under simulated operating conditions. Prior to off-site integrated testing, used equipment may be refurbished or replaced to new condition. Data collection for integrated testing may be fully representative of anticipated operating conditions.

12. EXPECTED RESULTS AND ACCEPTANCE CRITERIA

The following subsections outline the generic expected test results and acceptance criteria based on satisfying the ITS requirements specified in NSDB (BSC 2005). Reported deviations from these expectations should be subject to close inspection and further the evaluation. If necessary, additional testing may be required to verify data or provide additional information to enable a conclusive root cause analysis to be performed.

12.1 ACCELERATED TESTING

The completion of accelerated testing will demonstrate the satisfaction of applicable ITS reliability requirements specified in the NSDB (BSC 2005).

To achieve these requirements, it is expected that the SSCs may not require any unplanned maintenance. Failure of ITS components within this period, results that are not consistent with vendor data, and bench testing may be closely evaluated to determine root causes for any failures or problems found.

12.2 EXTENDED TESTING

Extended testing may provide added confidence that ITS requirements can be met with a degree or margin over an extended operational life. Therefore, successful extended testing may

conclude with results that further support accelerated testing. Extended testing may provide a basis for the timing of planned maintenance outages during which components and assemblies may be inspected and maintained.

12.3 SUSTAINED TESTING

Sustained testing may provide added confidence that ITS requirements can be met with a degree or margin under off-normal conditions. Therefore, successful sustained testing may conclude with results that further support accelerated and extended testing. Sustained testing may highlight potentially weak areas, demonstrate areas of unacceptable wear, and identify signs of fatigue. This testing may add confidence to the frequency of planned maintenance outages.

12.4 OFFSITE INTEGRATED TESTING

Off-site integrated testing will provide assurance the system will perform all required safety functions and that interactions with other equipment interfaces including recovery systems are as specified. During this testing, improvements may be highlighted that will be incorporated prior to delivery and installation of the equipment on site.

13. LOGIC TIES TO DESIGN ENGINEERING, PROCUREMENT, AND CONSTRUCTION

As stated previously, no design development requirements have been identified for the trolley turntables. The logic ties to Design Engineering, Procurement, and Construction organizations listed in Appendix D are listed as example only.

14. REFERENCES

The following documents were used in the preparation of this report:

ANSI/IEEE Std 352-1987. *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems*. New York, New York: The Institute of Electrical and Electronics Engineers. TIC: 246332.

IEEE Std 323TM-2003. 2004. *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*. New York, New York: Institute of Electrical and Electronics Engineers. TIC: 255697.

BSC (Bechtel SAIC Company) 2005. *Nuclear Safety Design Bases for License Application*. 000-30R-MGR0-00400-000-001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050308.0004.

COGEMA 2005. *Turntables—Gap Analysis Table*, COGEMA-C0115-EN-CLC-0024, Rev. 1. Las Vegas, NV: COGEMA Inc. (BSC Standard Document No. V0-M00Z-QPA0-05391-00323-001).

DOE (U.S. Department of Energy) 2004. *Quality Assurance Requirements and Description*. DOE/RW-0333P, Rev. 16. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

LP-ENG-014-BSC, Rev. 0, ICN 2. *Engineering Studies*.

LP SI.11Q-BSC, *Software Management*.

APPENDIX A: ITS SSCs DESIGN DEVELOPMENT NEEDS

NSDB Requirement	Applicable SSC	Design Development Needs					Comments
		Required Analysis	Required Drawings	Required Calculations	Required Modeling	Required Testing	
Turntables shall be designed for the stability and prevention of a tipover of any waste container on the table for loading conditions associated with a DBG-2 seismic event. In addition, an analysis shall demonstrate that the turntable has a sufficient seismic design margin to ensure that a no tipover safety function is maintained for loading conditions associated with a BDBG seismic event.	All load path SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
In the event of a credible fire in an area where waste forms are present, the temperature of machinery that handles or transports SNF/HLW shall not reach a level that would cause a drop of a cask (or a waste package) while on a turntable.	All load path SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
A tipover and breach of a cask while on a turntable that handles SNF/HLW due to uncontrolled movements produced by a loss of power or a spurious signal caused by a fire shall have a probability of less than 1×10^{-4} over the life of the facility.	Electrical disconnect and brake SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements
Loaded transfer trolleys shall not derail or drop their loads.	All load path SSCs, brake SSCs, bumper and stop SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards

NSDB Requirement	Applicable SSC	Design Development Needs					Comments
		Required Analysis	Required Drawings	Required Calculations	Required Modeling	Required Testing	
The rails and rail anchorages within the structure (DTF) shall be designed for loading conditions associated with a DBGM-2 seismic event. In addition, it shall be demonstrated that the rails and rail anchorages have a sufficient seismic design margin to ensure that a no derailment safety function is maintained for loading conditions associated with a BDBGM seismic event.	Rails and rail anchorage SSCs	N/A	N/A	N/A	N/A	N/A	Design development satisfied by codes and standards and supplemental requirements

APPENDIX B: ITS SSCS PROTOTYPE TESTING

ITS SSCs Prototype Testing	
ITS SSC	Test
No prototype testing of ITS SSCs is anticipated for the trolley turntables.	N/A

APPENDIX C: ITS SSCs DATA COLLECTION

ITS SSCs Data Collection	
ITS SSC	Potential Data Collection
No data collection of ITS SSCs is anticipated for the trolley turntables.	N/A

APPENDIX D: TROLLEY TURNTABLE DESIGN DEVELOPMENT MILESTONES

Design Development Activity	Development Activity Description	Project Phase	P3 Logic Tie Activity ID	P3 Logic Tie Activity Description	Target Start	Target Finish
Selection of SSCs	Selection of SSCs for detailed design	Procurement—Development of performance specification Procurement—Detailed design by vendor	RPPDFK20	MH Vendor Design—DTF Turntable	Sep 2007	Apr 2011
Engineering Calculations	Fire hazard analysis Structural and mechanical design Instrumentation and control and electrical design	Procurement—Detailed design by vendor	RPPDFK20	MH Vendor Design—DTF Turntable	Sep 2007	Apr 2011
			RPPDFK20	MH Fabrication—DTF Turntable	Sep 2007	Apr 2011
Computer Modeling	Interference and interface verification Finite element analysis	Procurement—Detailed design by vendor	RPPDFK20	MH Vendor Design—DTF Turntable	Sep 2007	Apr 2011
Fault Mode and Effects Analysis	FMEA of detailed design	Procurement—Development of performance specification Procurement—Detailed design by vendor	RPPDFK20	MH Vendor Design—DTF Turntable	Sep 2007	Apr 2011
Fault Tree Analysis	FTA of detailed design	Procurement—Development of performance specification Procurement—Detailed design by vendor	RPPDFK20	MH Vendor Design—DTF Turntable	Sep 2007	Apr 2011
Bench Testing	Bench testing <ul style="list-style-type: none"> Test preparation and procurement Accelerated testing Extended testing Sustained testing 	Procurement—Detailed design by vendor	RPPDFK20	MH Fabrication—DTF Turntable	Sep 2007	Apr 2011
Prototype Testing	Prototype testing <ul style="list-style-type: none"> Test specification and procedure Vendor test 	Procurement—Detailed design by vendor	RPPDFK20	MH Vendor Shop Test—DTF Turntable	Sep 2007	Apr 2011
Integrated Testing	Offsite integrated testing <ul style="list-style-type: none"> Test specification and procedure Testing 	Detailed design by vendor	RPPDFK20	MH Vendor Shop Test—DTF Turntable	Sep 2007	Apr 2011

NOTE: No design development activities are anticipated for the trolley turntables; however, the codes and standards and supplemental requirements given in the *Turntables—Gap Analysis Table* (COGEMA 2005) cover many of the above activities.

MH = mechanical handling